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STUDIES IN INDIAN LIVERWORTS : A REVIEW*

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I. Introduction and Historical Review

The liverworts have generally been assigned an important position in the evolution of plants. Morphologically also they show a great range of variations in the structure of the gametophyte as well as the sporophyte. For these reasons the group has attracted the attention of many botanists in Europe and America. In India, however, only a belated interest has been shown in the study of these plants.

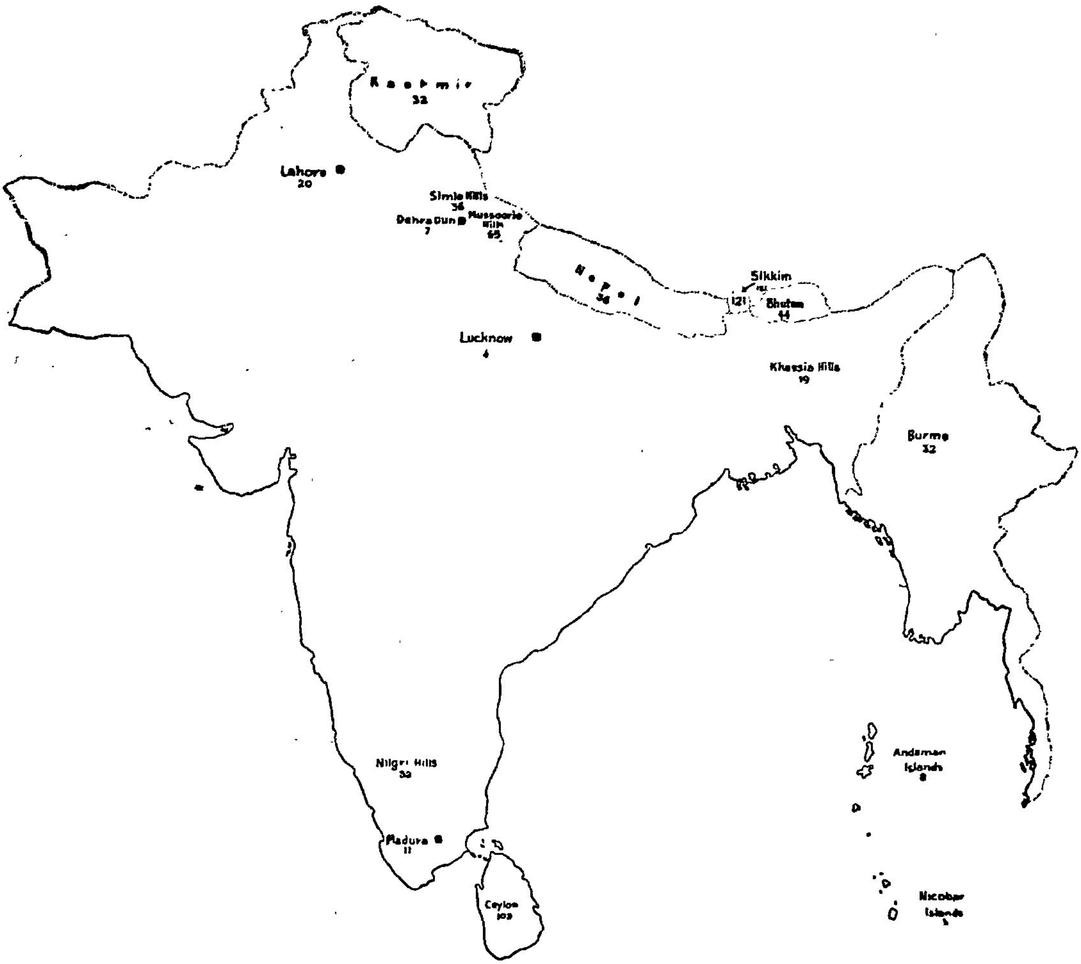
(i) **Early records of Liverworts of India and Griffith's contributions.**—The earliest record of the Indian liverworts, apart from those collected by Dr. Wallich and Wight and described later in the Synopsis Hepaticarum of Gottsche, Lindenberge et Nees (10), is a brief reference by Royle in the well known "Illustrations of the Botany and other Branches of Natural History of the Himalayan Mountains, Vol. I, 1839" (41). By this time William Griffith, who was originally an assistant surgeon in Madras, had already commenced his studies of the Indian Liverworts. In 1835 Griffith accompanied Dr. Wallich, who was then in charge of the Botanic Gardens at Calcutta, on an expedition to Assam in order to inspect the localities in which the tea plant grew wild (34). During this and the following year he made valuable collections from this region. Subsequent additions to these were made from Burma in 1837 and from Bhootan in 1838. It was chiefly during these excursions and during his short tenure of office as Superintendent of the Royal Botanic Gardens at Calcutta that Griffith compiled his valuable notes, "Notulae ad Plantae Asiaticae," with the accompanying set of plates, which were published after his death in 1849 as his Posthumous Memoirs (11, 12). About 50 species of liverworts are described in these works.

(ii) **Mitten's Work,** 1861.—In 1861 Mitten produced a comprehensive account of the Indian Liverworts in the Journal of the Proceedings of the Linnean Society (32). In these papers he presented a concise systematic account of all the species collected by Sir J. D. Hooker in the Himalayas and by Sir Joseph Hooker and Dr. Thomson in the Khasia Hills, as well as those gathered by Gardner and Thwaites in Ceylon. He has also included all the species described by Griffith in the Notulae ad Plantae Asiaticae and those described from India in the Synopsis Hepaticarum.

Since the publication of Mitten's work till about the close of the last century apparently no work was done on Indian liverworts except for collections by systematists, forest botanists, surveyors and travellers, prominent among whom were Brandis, Duthie, Gamble, Hartless, Bretaudeu, Gammie, Perrottet, Decoly and Schaul and Durel.

(iii) **Schiffner's work on Liverworts of Bhootan,** 1899.—Durel's collection was made in 1898 from British Bhootan between

Maria Basti and Labar at a height of 5,000-6,000 ft. and subsequently described by Professor Schiffner in 1899 (42). Out of the 35 species of liverworts described in this paper 10 species and 2 varieties were new to science.



(iv) **Liverworts of India in Stephani's Species Hepaticarum**, 1898-1925.—In 1898 Stephani started the publication of the Species Hepaticarum which deals with the liverwort flora of the whole world. The last volume of these comprehensive works was published in 1925. A census taken from Stephani's publications (44) reveals that out of about 525 species of liverworts occurring in India more than half are endemic.

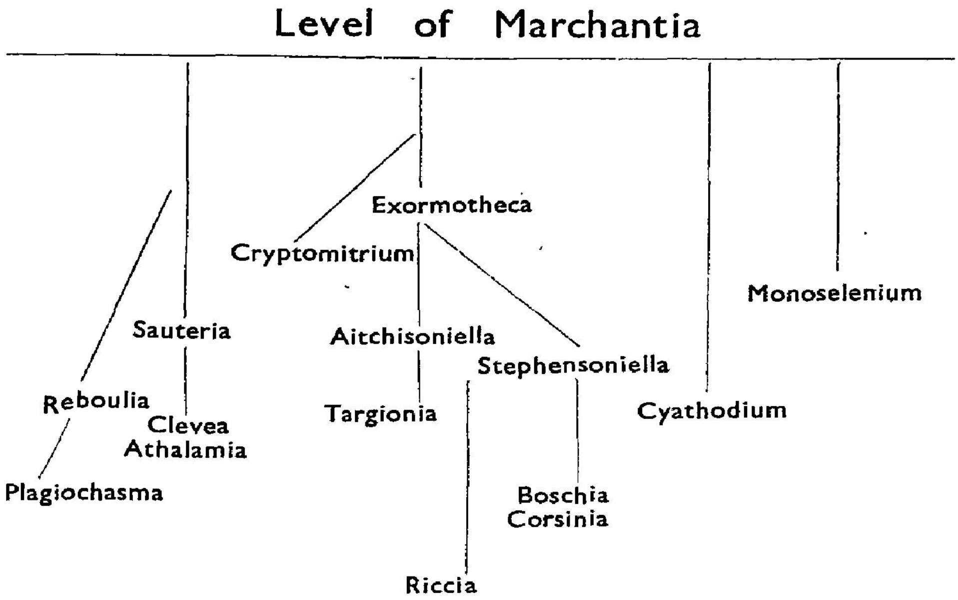
The following list and map gives the number of liverworts in some of the important localities on the basis of the data available in the Species Hepaticarum, supplemented from other works:—

1.	Sikkim	121
2.	Ceylon	103
3.	Mussoorie	65
4.	Bhootan	44
5.	Nepal	36
6.	Simla	36
7.	Kashmir	32
8.	Nilgiri Hills	32
9.	Burma	32
10.	Lahore	20
11.	Khasia Hills	19
12.	Madura	11
13.	Andamans	8
14.	Dehra Dun	7
15.	Nicobar	5
16.	Lucknow	5

In 1910 appeared a paper by Goebel on *Monoselenium tenerum*, a liverwort originally described by Griffith from Assam (11, 12). This plant was accidently transported to München (probably as spores) along with some tea plants which were obtained from Canton (34). The tea plants died but the soil was kept moist in the hope of germinating seeds, when *Monoselenium* turned up (34). As a result of his studies of this interesting liverwort Goebel was led to the important conclusion that the simpler members of the Marchantiales have been derived from the higher ones by reduction (8).

(v) **Kashyap's contributions,** 1912-1934.—About 1912 the late Prof. S. R. Kashyap, who will always be remembered as the father of Bryology in India, began his critical studies of the Indian liverworts and in 1914 was published his first paper "Morphological and biological notes on new and little known West-Himalayan liverworts," in the New Phytologist (13). The other two papers of this series were published later in the same journal (14, 15). In these papers Professor Kashyap enumerated 28 species of liverworts from this area and of these three genera and several species were new to Science. In the light of his studies of these Himalayan forms he strongly supported Goebel's view of reduction in the Marchantiales and added new facts in support of it (13-15). The

Indian liverworts provided him sufficient data to trace the details of reduction in several cases as shown below:—



Phylogeny of Marchantiales as suggested by Kashyap.

The results obtained by Kashyap from his investigations of other groups (13-17) convinced him of a wholesale reduction in the Hepaticae and he put forth ample evidence in support of this view in his Presidential Address to the Botany Section of the Sixth Indian Science Congress at Bombay in 1919 (18).

In 1920 (19) and 1921 (20) Professor Kashyap published accounts of the distribution of liverworts in the Western Himalayas and Ladak, embodying the results of his extensive travels in these regions.

An illustrated account of the Liverworts of the Western Himalayas and the Panjab Plain (Part I) was brought forth by Kashyap in 1929 (21). The second part of this valuable work, written in collaboration with Mr. R. S. Chopra, appeared in 1932 (23). These publications (21-23) have added greatly to our knowledge of the Indian Liverworts, especially those from the Himalayas, and they are of great help to the students of Indian Bryology. In all about 53 genera and 161 species were described and of these 4 genera and about 50 species were founded by Professor Kashyap himself.

(vi) **Gola's paper on Kashmir Liverworts,** 1914.—In 1914 a short note was published by Gola on the Liverworts of Kashmir (9). Eleven species were enumerated in this note and of these three were new to science.

(vii) **Other contributions to Indian Bryology.**—In addition to the works of the authors referred to above, contributions have also been made by Kashyap and Pandé (24), Sethi (43), and Chowdhury and Rajaram (5) from Lahore, Khanna (25-29) from Rangoon, Tiwari (46) from Benares, and Müller (33). A paper has also been published by Chalaud from Toulouse on "Mycorrhiza and tuberisation in *Sewardiella tuberifera*" (6). In his monograph, "Die Frullaniaceae der Indomalesischen Inseln" (48), Verdoorn has included a number of species of this interesting family from India. He has also published important information on some Indian Liverworts in the "Hepaticae Selectae et Criticae", series I and II (49) and III and IV (50).

(viii) **Work done by the author.**—In 1921 the author commenced his studies of the Indian liverworts. It was felt that a detailed investigation of some of the Indian types was very necessary not only because it may place students in Indian Universities, where Botany was becoming popular day by day, in possession of first-hand detailed knowledge of the local plants, but also because it may lead to further elucidation of certain important bryological problems. The following types were selected for this study:—

A. Anthocerotales.

1. *Notothylas indica* Kashyap.
2. *N. levieri* Schiffner MS.

B. Jungermanniales.

3. *Fossombronia himalayensis* Kashyap.
4. *Aneura indica* St.

C. Marchantiales.

5. *Riccia robusta* Kashyap.
6. *R. sanguinea* Kashyap.

The results of my investigations of these plants have been communicated to different sessions of the Indian Science Congress and in some cases have also been published in final form (24, 36-40).

(ix) **Future work.**—Turning our attention to the future researches in Indian Hepaticology it may be said that there is a great field for many interesting and fruitful lines of investigation. The lofty Himalayas and the rain forests provide an ideal home for the growth of liverworts and a record of 525 species from India certainly represents only a fraction of the Hepatic vegetation. Further collections and their systematic examination on the lines begun by the late Professor S. R. Kashyap will surely lead to useful results.

Another and undoubtedly a more important line of research would be a detailed investigation of the life-history of some of the new and interesting genera and species especially the intermediate and the connecting types like *Sewardiella, Aitchisoniella, Stephen-*

soniella, etc. Prof. Kashyap was able to make use of the material he investigated for a fresh study of the relationships. Further studies might reveal striking results which would be helpful in the elucidation of the relationships and the phylogeny of this interesting group of plants.

Still another aspect of future investigation is the study of this group in its natural habitat, from the ecological, physiological and distribution points of view.

II. Some general considerations

In the foregoing pages an attempt was made to summarise our present knowledge of Indian Hepaticology. My observations on the different species studied are given along with their published accounts. Certain considerations of general interest may be briefly reviewed here.

(*a*) **Distribution of Liverworts in the Himalayas.**—One of these interesting problems is the distribution of liverworts in the Himalayas. Professor Kashyap has shown (19, 20) that in the Western Himalayas

(i) in the outer range the number of species of liverworts, as well as the number of individuals of a particular species at a given altitude, decreases from the East to the West,

(ii) in passing vertically upwards from the plains the number of liverworts increases up to a height of 7,000 ft. in the outer Himalayas, after which it decreases; further that the same law holds good for the middle and inner ranges,

(iii) the number of liverworts in the middle ranges is less than that in the outer Himalayas and

(iv) there are no liverworts beyond the inner ranges.

Sufficient evidence is available in support of the above from the facts at present known. In the accompanying list is given the number of liverworts from some of the important localities in the Himalayas.

Locality		*Height above Sea level*	*Number of species of liverworts*
Eastern Himalayas	Sikkim ..	7,000 — 8,000 ft.	121
	Bhootan ..	6,000 — 7,000 ft.	44
	Nepal ..	6,000 — 7,000 ft.	36
Western Himalayas	Mussoorie ..	6,000 — 8,000 ft.	65
	Simla ..	6,000 — 8,000 ft.	36
	Kashmir Valley ..	Variable.	32

A perusal of the above table shows that the liverwort flora becomes poorer in the Western Himalayas as we proceed from Mussoorie in the east to Kashmir in the west. Probably the same law may hold good for the Himalayas as a whole, including the localities in the Eastern Himalayas, as is evident from the fact that

the number of liverworts recorded from Sikkim is 121, a figure which is almost double the number recorded from any other locality at the corresponding height to the west of it, although the flora of some of these localities has been more thoroughly explored.

The reason that the number of liverwort species recorded from Bhootan and Nepal is so low is probably because the flora of these independent territories is yet very imperfectly known. More extensive collections, especially from the Eastern Himalayas, are likely to add more facts which would supplement these data. Professor Kashyap's view also appears to hold good for the vertical distribution of these plants. My own experience of the liverwort flora of the Kumaon hills and certain parts of the Western Himalayas has led me to the same conclusion. At Dehra Dun which lies at the base of the Mussoorie Hills, only six or seven species of liverworts are found, but the number increases as we ascend to Mussoorie (7,000-8,000 ft.) where as many as 65 species are known to occur. A similar condition is also found in certain other parts of the Western Himalayas. Thus at Kathgodam, which is situated at the foot of the Naini Tal hills, only a few liverworts are met with, while at Naini Tal itself (7,000-8,000 ft.) the liverwort flora is very rich. Beyond a height of about 8,000 ft. in the outer Himalayas the liverwort flora becomes poorer.

Our knowledge of the liverwort flora of the higher altitudes and the interior of the Himalayas is yet far from complete, but whatever is known at present supports the conclusions arrived at by Professor Kashyap with regard to the distribution of this group in these regions.

(*b*) **Reduction as a factor in the origin of simpler liverworts.**—The question as to whether the simpler members of the Hepaticae have given rise to more complex ones by gradual evolution and amplification, or whether, on the contrary, the former have arisen from the latter by reduction and simplification, is one that has frequently been discussed. Underwood (47), Campbell (3), Cavers (4), Lotsy (31) and Bower (2) have argued in favour of the former view. The opposite view has gained prominence since the publication of Professor Goebel's researches on *Monoselenium tenerum* (8). Prof. Kashyap has greatly amplified this from his studies of the Indian liverworts (13-15, 18). While it cannot be denied that an important problem such as this could only be properly discussed after a comprehensive investigation of many more genera and species of the different groups of liverworts and while I am also fully aware of the limitations of my own work in this connection, yet certain interesting features observed by me in some of the species investigated induce me to say a few words on the subject so far as it concerns those particular cases.

In my work on *Notothylas levieri* Schiffner, I had occasion to refer to this point (40). The structure of the capsule and its mode of dehiscence are features of special interest. As usual in

the genus, the sporogonium in both the Indian species studied (*N. indica* Kash. and *N. levieri* Schiffner) is horizontal and ensheathed in an involucre and although valves capable of hygroscopic movements and provided with well developed sutures for dehiscence are present, the spores are generally liberated by the decay of the capsule wall. In some cases, however, the sporogonia may dehisce normally but even here the dehiscence occurs generally only along one of the sutures. This imperfect mode of spore-liberation, even when there is an efficient provision for normal dehiscence, together with the fact that the sporogonial wall contains photosynthetic tissue although there are no stomata, would indicate that *Notothylas* is a reduced genus, a view which has been held by some other bryologists (1, 7, 21). I have shown conclusively that in *N. levieri*, the only noncolumellate species which has so far been fully investigated, the sporogenous tissue is derived only from the endothecium; while in *N. indica* it is formed from the amphithecium, and the endothecium gives rise to the columella as in *Anthoceros*. If our reasoning is correct and if we are justified in regarding *Notothylas* as a reduced genus, the obvious conclusion would be that the columellate species are comparatively primitive (least reduced) while the non-columellate are relatively more advanced (most reduced). This would mean that the amphithecial archesporium is a primitive character and the endothecial archesporium a reduced character. This might possibly also indicate that the Anthocerotales, in all of which (except some species of *Notothylas*) the sporogenous tisue arises from the amphithecium are primitive; while the Jungermanniales and the Marchantiales, etc., in which the sporogenous tissue arises from the endothecium, are reduced. But it must be borne in mind that we cannot generalise without more intensive work on a fairly large number of genera and species of different groups. However, it seems quite reasonable to suppose that *Notothylas* is a reduced genus in which the columellate species, like *N. indica,* are primitive, while the non-columellate species, like *N. levieri*, are reduced. A full discussion of this question is given in my paper on *Notothylas levieri* (40).

Another case to which I might refer here is that of *Riccia robusta* Kashyap. This plant, which had previously been investigated by Kashyap (16) and others (30, 35), was recently studied by me (38). It seems that the scales may be present in this species under certain conditions but not under others. Even in those cases when these are present they are small, rudimentary, deciduous structures confined to the apex. It does not seem at all unlikely that these organs represent the vestiges of once well developed functional scales. According to Professor Kashyap, in the specimens of this species from Lahul, there are no tuberculate rhizoids (21). In *R. crystallina,* which appears to be synonymous with *R. robusta* St. Nicholson, (33a, p. 142), Pagan noticed small sterile nutritive cells (35); but they have not been seen by others. This might be due

to the fact that they are formed only occasionally. Another interesting feature of *R. robusta,* as I have pointed out elsewhere (38), is that sometimes two archegonia are found together in a single chamber. This may only be one of the many abnormalities abundant in the plant-kingdom, or it might indicate the recurrence of an ancestral character, thereby suggesting the origin of *Riccia robusta* from ancestors in which the archegonia were grouped together. In any case, all the above features of *R. robusta* taken together would tend to indicate that the species is reduced.

A consideration of cases like those outlined above seems to make it apparent that reduction has played an important part in the origin of the simpler members of the Hepaticae.

III. Acknowledgments

I cannot adequately express my indebtedness to Professor B. Sahni, at whose suggestion the work was originally begun, for all the kindnesses during the course of my investigations. Not only have I had the benefit of his kindly advice and criticism but also a free access to his valuable personal library. I am also extremely grateful to him for placing at my disposal his valuable and well fixed material of *Fossombronia himalayensis* Kashyap. My grateful thanks are also due to the late Professor S. R. Kashyap, with whom I had the privilege of being associated both as a student and a joint worker, for many helpful suggestions and criticisms, as well as for the identification of some of the specimens from my own collections. I also wish to record here my thanks to Messrs. R. S. Sharma and V. S. Sharma for help in the preparation of some of the drawings and photographs reproduced here and elsewhere.

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ON INDIAN SPECIES OF THE GENUS *ANTHOCEROS* LINN. WITH A DESCRIPTION OF A NEW SPECIES FROM TRAVANCORE

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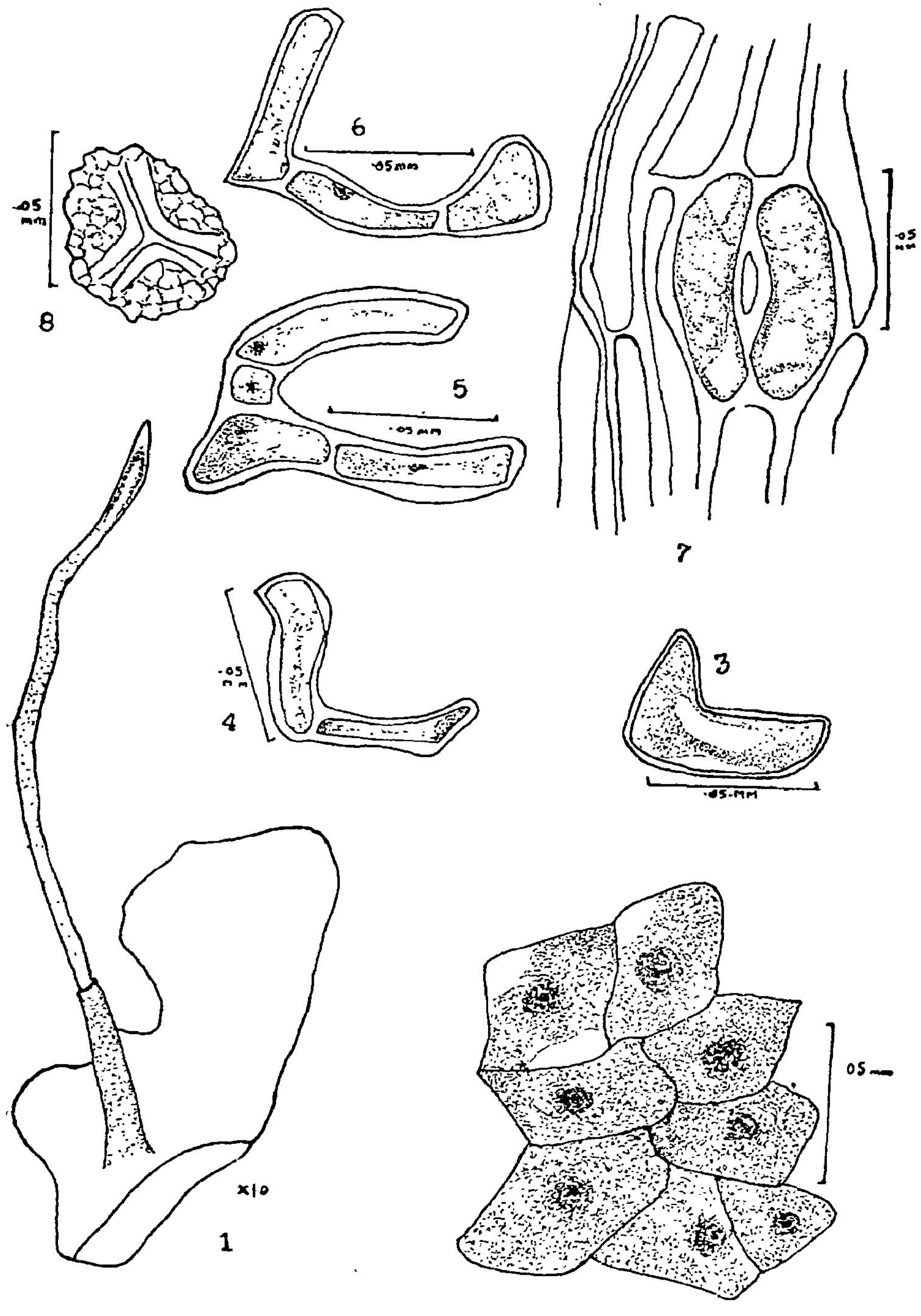
In 1915 Kashyap described from India two new species of the genus *Anthoceros* Linn., and in 1916 Stephani added twelve new Indian species. Of these latter, one name, *A. himalayensis,* had already been assigned by Kashyap to another species in 1915 and hence a distinctive name *A. Stephanii* is proposed. In 1917, Kashyap added another species to Indian Anthoceros. In 1923 Stephani further added four new species. Kashyap (1929) claimed that *A. Butleri* Stephani 1916 and *A. Longii* Stephani 1916 were probably synonymous with *A. erectus* Kashyap 1915. This appears to be erroneous, because *A. Butleri* Stephani 1916 and *A. Longii* Stephani 1915 differ from each other in many of the characters on which the classification of the genus is based—the colour of the spore, monoecious or dioecius habit, size of the plant and size of the involucre. The first species (*A. Butleri* Stephani 1916) differs from *A. erectus* Kashyap 1915 in being monoecious and having the spore pale coloured, the latter (*A. Longii* Stephani 1916) in being monoecious and having a smaller size of the involucre and a shorter capsule. Further Kashyap (1929) considered *A. Gollani* Stephani 1916 to be perhaps the same as *A. chambensis* Kashyap 1917, but the monoecious nature of the former together with the size of the involucre and the colour of the spore definitely dismisses his surmise. A comparative table of the characters of the so far known Indian species of *Anthoceros* is herewith provided.

For the material of the new species which forms the basis of this paper the writer is indebted to Professor T. K. Koshy, Maharaja's College of Science, Trivandrum, to whom he wishes to



Anthoceros Koshii sp. nov. (Figs. 1-8.)

1. Female plant. 2. Dorsal epidermal cells. 3—6. Pseudoelators. 7. Capsule wall showing stoma. 8. Spore.

express his thanks. Though the material was rather scanty it was in exceedingly good state of preservation. Thanks are also due to Prof. S. L. Ghose of Punjab University for the courtesy of providing co-type specimens of Kashyap's species from Kashyap's collection.

Of the known species of *Anthoceros* with dark spores the following are dioecious: *A. minutus* Mitten, *A. myriandroecius* Stephani 1916, *A. cucullatus* Stephani 1916, *A. lamellutus* Stephani 1916, *A. Weistii* Khanna 1932, *A. erectus* Kashyap 1915, *A. telaganus* Stephani 1916, *A. Parkinsonii* Khanna 1933, *A. chevalieri* Stephani 1916, *A. chambensis* Kashyap 1917, *A. Feridinandi* Stephani 1916, *A. Miyokeanus* Stephani 1916, *A. Faurianus* Stephani 1916. The present form differs from *A. minutus* Mitten by the longer size of the capsule and the bigger spores; from *A. myriandroecius* Stephani 1916, by the solid structure of thallus, the bigger involucre and the shorter capsule; from *A. cucullatus* Stephani 1916 by the shorter capsule and the bigger spores; from *A. lamellutus* 1916, by the shorter involucre and capsule and the bigger spores; *A. Weistii* Khanna 1932, by the smaller size of the plants, the shorter involucre and capsule; from *A. erectus* Kashyap 1916, by the solid structure of the thallus, the absence of large chambers in the thallus filled with mucilage and the shorter capsule with the bigger spores; from *A. telaganus* Stephani 1916, the bigger plant, the shorter involucre and capsule and the bigger spores; from *A. Parkinsonii* Khanna 1933, the longer involucre and the bigger spores; from *A. chevalieri* Stephani 1916 by the smaller size of the plant and the shorter capsule; *A. chambensis* Kashyap 1917, by the longer involucre, the shorter capsule and the bigger spores; from *A. Feridinandi* Stephani 1916, by the shorter involucre and capsule and the bigger spores; from *A. Miyokeanus* Stephani 1916 by the smaller size of the plants and the longer capsule; from *A. faurianus* Stephani 1916, by the shorter capsule and the bigger spores. It is, therefore, necessary to create a new species, for which I propose the name *Anthoceros Koshii* sp. nov.

DESCRIPTION

Anthoceros Koshii sp. nov.*

Dioecious. In pale green patches. Thallus 5-12 in diameter, depressed in centre, with margins slightly ascending and undulated; surface cells 0·025—0·04 x 0·045—0·07. Transverse section of middle of thallus 7—12 cells, solid. Involucre 2·8—3·6 long x 0·5—0·8 broad, cylinderical, slightly narrowed towards the apex. Capsule 12—15 long x 0·2—0·4 broad, stomata variable, averaging 0·075 x 0·05. Spores 0·055—0·065 dark papillate pseudoelators. Antheridia in groups of 2—8, scattered over the dorsal surface of the thallus.

Locality: Travancore: Peermade.

*All measurements in mm.

Comparative Table of the Characters

	Sexuality.	Plant Size.	Structure.
A. *alpinus* Stephani 1923 ..	Autoicous	5·0	Solid
A. *angustus* Stephani 1916 ..	Monoecious	20·0	Cavernous
A. *Butleri* Stephani 1916 ..	Monoecious	12·0	Cavernous
A. *cataractarum* Stephani 1916..	Monoecious	25·0	Solid
A. *chambensis* Kashyap 1917 ..	Dioecious	30·0	Cavernous
A. *erectus* Kashyap 1915 ..	Dioecious	10·0	Cavernous
A. *fuscus* Stephani 1916 ..	Monoecious	10·0	Cavernous
A. *Gollani* Stephani 1916 ..	Monoecious	10·0	Cavernous
A. *grosse-involucratus* Stephani 1923 ..	Autoicous	15·0	Cavernous
A. *himalayensis* Kashyap 1915..	Dioecious	†20·0	
A. *indicus* Stephani 1916 ..	Monoecious	15·0	Cavernous
A. *Jackii* Stephani 1923 ..	Autoicous	15·0	Solid
A. *Koshii* sp. nov. ..	Dioecious	10·0	Solid
A. *Longii* Stephani 1916 ..	Monoecious	5·0	Cavernous
A. *macrosporus* Stephani 1916 ..	Autoicous	20·0	Cavernous
A. *Meeboldii* Stephani 1916 ..	Autoicous	10 0	Solid
A. *notothyloides* Stephani 1923..	Autoicous	10·0	Cavernous
A. *Stephanii* Khanna ..	Monoecious	8·0	Cavernous
A. *subtilis* Stephani 1916 ..	Monoecious	5·0	Cavernous
A. *tenax* Stephani 1916 ..	Monoecious	20·0	Cavernous

D = Dark P = Pale; Op. = Opaque

of the Indian species of *Anthoceros*

Involucre.	Capsule.	Spores.	Distribution.
4·0	30·0	D. 0·054	India : Mussoorie
3·0	20·0	D. 0·036	Himalaya
5·0	20·0	P. 0·036	Himalaya
2·0	20·0	B. 0·036	Himalaya
2·5	25·0	Op. 0·04-·048	Chamba Valley; Punjab
5·0	30·0	B. 0·03-0·04	Outer and Kumaon Himalayas, Madras, Travancore
3·0	25·0	D. 0·045	Anam (India Orientalis)
4·0	30·0	P. 0·036	Himalaya
8·0	45·0	D. 0·036	Sikkim Himalaya
5·0	30·0	Y. 0·025	Common throughout the outer and the Kumaon Himalayas. Rare y in Lahore
3·0	20-0	D. 0·036	India Orientalis, Mysore
3·0	30·0	Y. 0·036	Himalaya : Mussoorie
2·8-3·6	12-15	D. 0·55-0·65	S. India : Peermade
2·0	20·0	B. 0·045	Himalaya : Simla
4·0	40·0	B. 0·054	India Orientalis : Bhor Ghat
2·0	30·0	B. 0·045	India Orientalis : Travancore
3·0	15·0	B. 0·036	India
3·0	30·0	D. 0·036	Himalaya
2·0	12·0	D. 0·036	India : Mangalore
4·0	30·0	P 0·036	Himalaya

B. = Black; Y. = Yellow.

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EXTRA-FLORAL NECTARIES IN *TECOMA CAPENSIS* LINDL.

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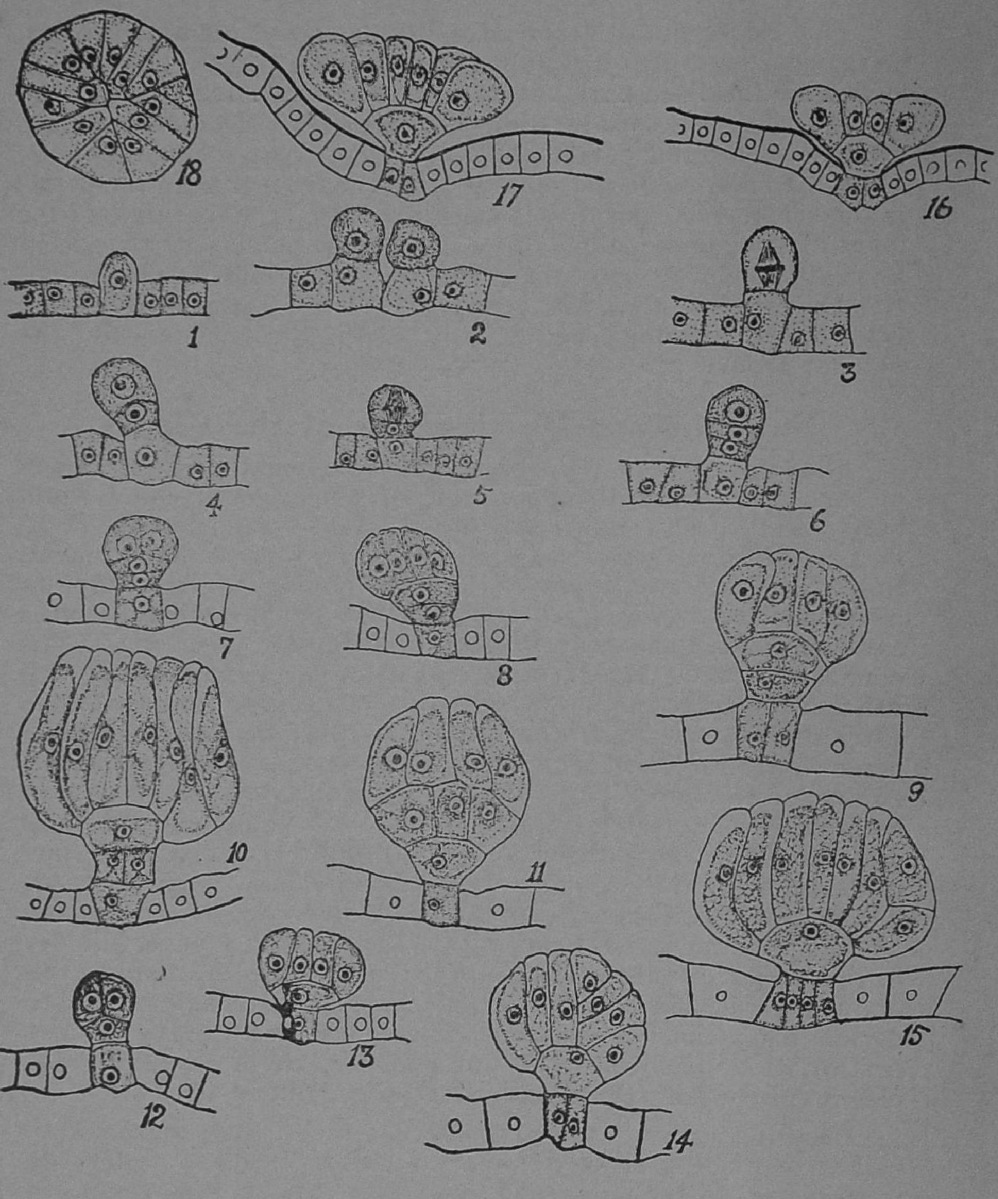
Introduction

Besides the anatomical peculiarities, the family Bignoniaceae possesses, various other features uncommon in allied families. Solereder (1908, p. 601) mentions epidermal out-growths in various genera of this family, which may be unicellular or multicellular trichomes, branched or unbranched. In addition to the trichomes, multicellular glands, and patelliform glands are abundantly found in many parts of the plant. In various plants examined by him and by others, the patelliform glands were found to excrete sugary juice. Rao (1926, p. 113) described such extra-floral nectaries in *Spathodea stipulata* Wall besides the epidermal multicellular glands. He found these nectaries abundant on the abaxial side of all the floral and foliar parts, scattered or forming local aggregations and they excreted both cane-sugar and grape-sugar. The glands on the inner side of the calyx were found by Haberlandt (1914, p. 501) in *Spathodea campanulata* and by Rao (1926, p. 113) in *Spathodea stipulata* Wall to function as water excreting organs. Morini (Solereder, 1908, p. 601) observed such glands in *Bignonia grandiflora* and *Tecoma radicans*.

In the present work, the extra-floral nectaries in *Tecoma capensis* Lindl. were studied and the results are recorded.

Distribution of Glands

(i) *Glandular Hairs*—Multicellular glandular epidermal outgrowths occur in abundance in all aerial parts of the plant, including both vegetative and reproductive and are uniformly distributed; they have, however, different anatomical structures. On the morphologically lower side of the calyx, corolla and the leaves, there occur certain glandular hairs (Figs. 16-18) which look different from those distributed on the morphologically upper side of these organs and the stems (Figs. 1-15).



Figs. 1—18. *Tecoma capensis* Lindl.

Figs. 1-11. Stages in the development of the glandular hairs on the morphologically upper side of the floral and foliar parts. X 460. Figs. 12-15. A second series of development of similar glands on the same side of the floral and foliar parts. X 460. Figs. 16-17. Fully developed stages of the glandular hairs on the morphologically lower side of the floral and the foliar parts. X 460. Fig. 18. Surface view of a gland, the side view of which is represented in Fig. 17. X 460.

(ii) *Extra-floral Nectaries.*—Besides these glandular hairs, there occur patelliform glands, the so called extra-floral nectaries in certain localised parts of the calyx, corolla and the petiole. In both calyx and corolla, they occur always on the dorsal surface of those sepals and petals which are away from the mother axis. Their distribution on the sepal is different from that on the petal; in the sepal, their position is marginal along the margins of the lobes of the gamosepalous calyx and in the petals, their position is central, along both the sides of the midrib (Fig. 23). In the petioles, they are restricted to the apex only, just below the lamina and along both the ridges of the petiolar groove.

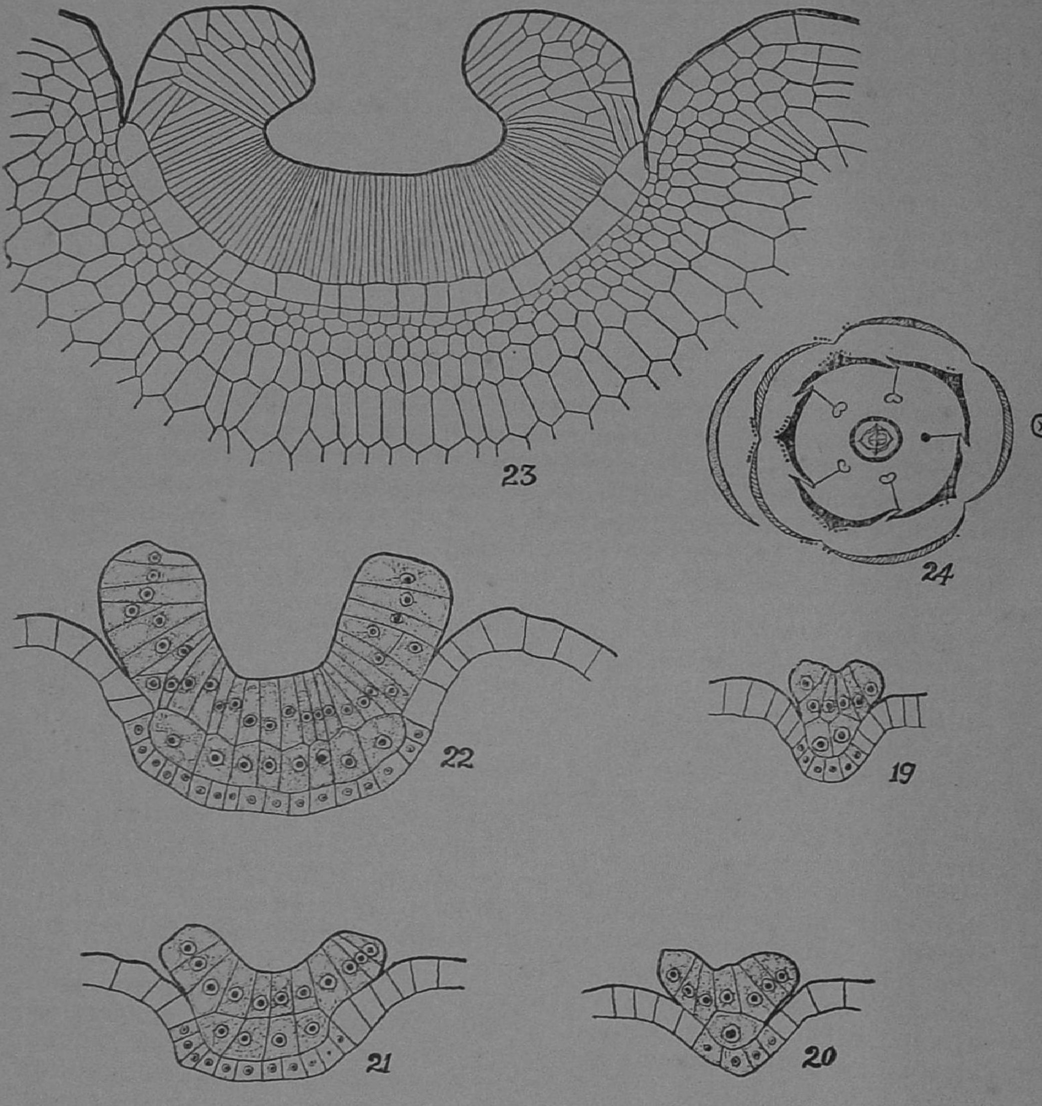
Structure and Development of the Glands

Glandular Hairs.—Progressive development of these hairs on the morphologically upper side of the vegetative and floral parts have been shown in figures 1-11 and figures 12-15 in two different series. Detailed study of these hairs shows that there are two types of hairs belonging to two different developmental series. All of them are epidermal outgrowths and they begin their early development in the same way. The epidermal cell at regular intervals enlarges in dimension with dense cytoplasm and large nucleus; it devides into two cells (Fig. 2), the apical cell by two further divisions forms a row of three cells (Fig. 6), or by a single transverse divison forms a two-celled row (Fig. 12). Further division takes place mostly in the apical cell by vertical walls (Figs. 7-9). Sometimes the basal and the middle cells divide (Figs. 10 and 11). The epidermal cell supporting the glandular hair may divide by vertical walls. The second series starts from the two celled-row by the division of the apical cell by vertical walls. The stalk cell never divides in this series and the stalk is always represented by a single cell but the epidermal cell supporting the glandular hair is seen to divide many times (Fig. 15). The apical cell always divides first of all by vertical walls, but later on, these resultant cells may divide by transverse walls also (Figs. 14 and 15).

Development of the glandular hairs on the morphologically lower side is exactly similar to that of the glands belonging to the series of the two-celled row. Here the stalk is composed of a single cell only and the apical cell divides always by vertical walls and never transversely. The epidermal cell just below the gland divides very often (Figs. 16 and 17).

Extra-floral nectaries.—They are found in pits formed by the undulation of the epidermis. They form cup-like structures, composed of club shaped cells arranged vertically on a sub-hymenial layer lining the epidermis (Fig. 23). The sub-hymenial layer consists of a single layer of cells lying outside the epidermis and supporting the patelliform glands above. All these glandular cells are not of the same size, those supported by the uniseriate stalk cells forming the sub-hymenial layer, are

much elongated and are mostly vertical in their arrangement whereas those glandular cells towards the margins are not so much elongated and they are comparatively much broader. These marginal cells are unsupported by the stalk and are arranged almost transversely (Fig. 23). The epidermal layer supporting the stalk is composed of comparatively smaller cells but with denser cytoplasm (Fig. 22).



Figs. 19—24. *Tecoma capensis* Lindl.

Figs. 19-22. Stages in the development of the nectar excreting patelliform glands on the calyx. X 460. Fig. 23, Fully developed stage of an extra-floral nectary. X 200. Fig. 24. Floral diagram of *Tecoma capensis* Lindl. showing the locotion of the extra-floral nectaries.

Such a nectary in its early stages of development looks much similar to a glandular hair developed on the dorsal side of the organs (Compare fig. 16 and fig. 20). In both the cases the stalk consists of a single cell, but later in the case of the nectaries, it divides gradually into a number of cells simultaneously with the division of the glandular cells above. Thus these nectaries like the glandular hairs are epidermal outgrowths which differentiate very soon into much complicated structures. Development of these glandular hairs and the so-called extra-floral nectaries suggest the origin of the latter from the former, the greater complexity of the latter being due to the tendency to increase the area of secretion. Origin and full development of these glandular hairs and nectaries have been noticed much before the differentiation of the sporogenous tissue in the ovules and in the anther. *Tecoma capensis* Lindl. possesses true nectaries also but their development is fundamentally different from these extra-floral ones; they are composed of cortical tissue and are developed internal to the epidermis.

Nature of Secretion

Glandular Hairs.—The nature of the glandular hair, their denser cytoplasm and comparatively bigger nucleus suggest their secreting function. Washings with distilled water from the leaf surface, where the patelliform glands are absent, give no test for sugar or any salt and therefore, if they actually secrete anything, it must be pure water and they must be doing the work of hydathodes only, as Haberlandt (1914, p. 501) has suggested.

Extra-floral nectaries.—Washings of the flowers with distilled water give distinct tests for glucose and cane-sugar. Such glands on the calyx give tests for the sugars many days before anthesis and black ants in large numbers are found visiting the flowers both day and night. Nectaries are present only on the outer surface of the calyx and corolla away from the mother axis, so that when the mother axis remains vertically up, the nectaries face vertically down by the bending of the pedicel. If the mother axis of the inflorescence happens to lie differently other than vertical, the pedicels of the flowers twist through different angles even up to 180° to keep the nectaries vertically down. The petioles also show different orientations to keep its nectaries vertically down. This sort of apparently downward position of the nectaries is most probably for their protection against rain and the sun. This is certainly a good protection against rain, because the ants are found gathering honey even after a heavy shower. Petioles in the shade do not show bending for the protection of the honey in their nectaries against drying up in the sun. This suggests that it is not gravity but light which brings about the orientation of the petioles and the flowers for the protection of the honey in their patelliform glands.

Discussion

Origin of the extra-floral nectaries.—Haberlandt (1914, p. 501) and Rao (1926, p. 113) think that the origin of these nectaries is from the glandular hairs. A study of the progressive development of the different kinds of glandular hairs and the extra-floral nectaries confirms this view.

Function of the nectaries.—It is difficult to suggest anything regarding on the function of such patelliform glands. Haberlandt (1914, p. 501) suggested that such glands are further additions to the secretory function of the normal floral nectaries which are not in these plants at a high state of differentiation. This suggestion is rather ambiguous, because the floral nectaries secrete relatively so little of honey that its profuse secretion from these glands keeps away the visitors from the true nectaries and thus hindering cross-pollination which would have been otherwise possible. Another interesting feature is that the nectar is secreted from the very early stage of the buds and much before anthesis. It seems that these patelliform glands keep away the unwelcome ants from visiting the flowers, and thereby probably favour self-pollination.

Summary

1. Glandular hairs are found in *Tecoma capensis* Lindl. in floral and foliar parts, distributed uniformly. They are of three different types.
2. Patelliform glands are present on the dorsal surface of the calyx and corolla and on the ventral surface of the petioles.
3. Patelliform or the so-called extra-floral nectaries excrete glucose and cane-sugar and the glandular hairs excrete water.
4. All these different types of water excreting or nectar excreting glands are purely the modifications of the outgrowth of the epidermal cells.
5. A study of the gradual development of all kinds of epidermal outgrowths suggests the origin of the nectar excreting patelliform glands from the glandular hairs.

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* SOME ECOLOGICAL ASPECTS OF THE UPPER GANGETIC FLORA

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Introduction

The Upper Gangetic Plain is a vast expanse of flat country. It is mostly under cultivation but grass covered waste land or thorny scrub are found in certain areas. The forests occur at the foot of the Himalayas which forms the northern boundary of this great plain. The soil is all alluvial, deposited in recent times. Its structure ranges from sand through various mixtures of sand and clay to fine clay. The older alluvium often contains deposits of calcium carbonate in irregular nodules, locally called "Kankar."

The nearest large body of water is the Bay of Bengal which is more than 500 miles away. The climate, therefore, is distinctly continental and shows a large range of temperature between summer and winter. Owing to monsoon conditions the year is divided into three seasons, *viz.*,

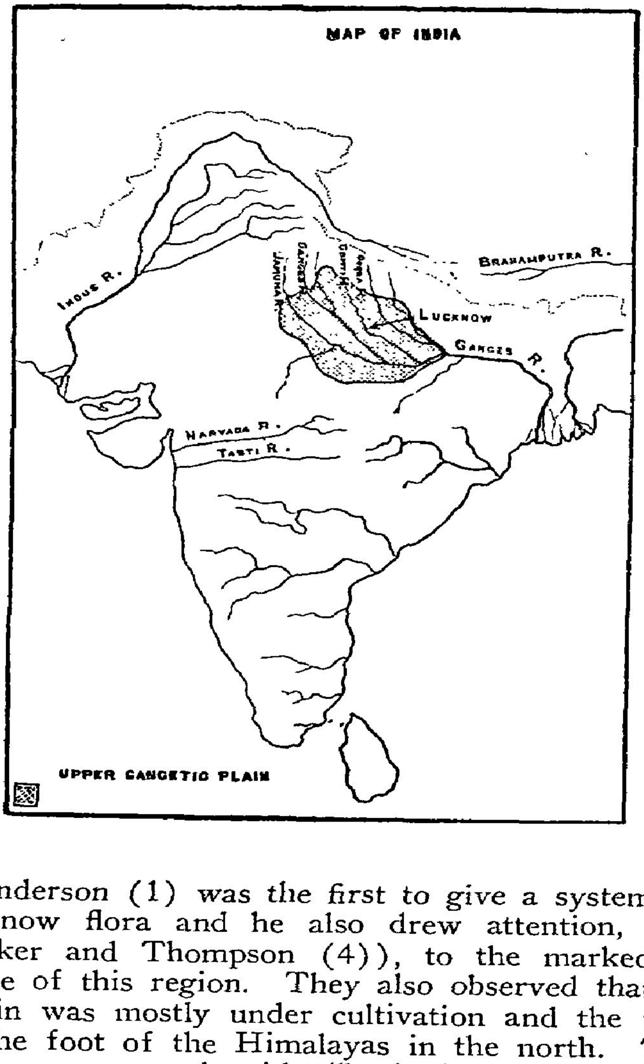
(i) the Rainy season from the last week of June to October,

(ii) the Winter season from October to February and

(iii) the Summer season from March to the third week of June.

* A part of this paper under the heading "On some aspects of the Ecology of Plants of the Upper Gangetic Plain" was read before the Botanical Society, University College, London, in March 1934.

Lucknow, 26·52 N latitude and 80·58 E longitude, is situated on the right and south bank of the Gomti River, a northern tributary of the Ganges. The mean height is about 365 feet above sea level.



Thos. Anderson (1) was the first to give a systematic account of the Lucknow flora and he also drew attention, like several others (Hooker and Thompson (4)), to the marked periodicity of the climate of this region. They also observed that the Upper Gangetic Plain was mostly under cultivation and the forests were confined to the foot of the Himalayas in the north. The uncultivated parts were covered with "bush jungles". Schimper (9) classified the xerophilous shrubs and trees that are found on the waste-land as "thorn-scrub". Dudgeon (3) states that the present vegetation is in the dry meadow stage and would develop into a deciduous monsoon forest if left undisturbed by man. Saxton (8) has tried to group the plants of different seasons into a number of Synusia (Gam's). A detailed investigation of the ecology of this region has not been made so far and this paper is a preliminary attempt to correlate the various edaphic and

climatic factors with the nature and growth of plants in the vicinity of Lucknow.

The work embodied in this paper was carried out in the Botany Department of Lucknow University during 1931-32. It was started at the suggestion of the late Dr. S. K. Mukerjee, D.Sc. (London), F.L.S. for whose inspiration and constant guidance I am deeply grateful. I am also very thankful to Professor B. Sahni, F.R.S., for his kind help and permission to consult the manuscripts of the late Dr. S. K. Mukerjee from which some references to literature were of great use. My thanks are also due to the Librarian, India House, London, for permitting me the use of the meteorological tables. I am very much indebted to Professor E. J. Salisbury, F.R.S., for much helpful advice and criticisms and for kindly going through the manuscript. The map has been drawn by Mr. V. S. Sharma, the laboratory assistant, to whom I am very thankful.

Methods

The methods of investigation were those suggested by Clements (2). Ten permanent quadrats of 1 square metre each were laid out in different but similar localities near Lucknow. The number and kind of plants were recorded on monthly, sometimes fortnightly, visits. On every visit to the quadrats, air and soil temperatures, light intensity and wind velocity were recorded. At the same time a weighed quantity of the soil from different depths in these quadrats was brought to the laboratory. This soil was heated to 105°C until it attained constant weight and the water content was calculated from the loss in weight.

The hydrogen-ion-concentration of the soils was determined by the colorimetric method with British Drug House reagents and buffer standards. The total carbonate content was determined with the help of Collin's Calcimetre. The Diphenylamine test was employed in order to find out roughly the amount of nitrates present in the soil. The soil was treated with toluene before it was brought to the laboratory in order to eliminate any error caused by the denitrifying bacteria. The loss on ignition was determined by finding out the loss of weight on heating the soil till it attained constant weight. Each of these determinations were carried out on the soils collected on every visit to the quadrats.

Discussion of Results

The localities in which these quadrats were situated were all similar and each quadrat acted as a check to the other. The following conclusions are based on the results obtained from all the quadrats taken together. It has been pointed out that there are

three seasons in a year and in the following description the various aspects of the ecology are dealt with from one season to the other beginning with the rainy season.

1. *The Rainy Season*:—The rainy season extended, as it usually does, from the last week of June to the middle of October in the year investigated. The maximum temperature varied from 93°F. in July to 88°F. in October, and minimum temperature varied from 80°F. in July to 70°F. in October. The range between maximum and minimum temperature during this season was 11°F. in August and 12°F. in September and this range gradually increased until in February it was 30°F. as shown in Table I.

TABLE I

Mean temperature in degrees Fahrenheit

(From Meteorological Tables)

—	June 1931	July 1931	August 1931	September 1931	October 1931	November 1931	December 1931	January 1932	February 1932	March 1932	April 1932	May 1932
Maximum Temperature ..	106·8	93	91·4	90·4	88·6	83·6	77·0	78·5	80·0	92·7	101·6	106·3
Minimum Temperature ..	83	79·5	80·0	77·7	70·3	55·9	50·5	49·6	50·3	62·2	71·3	78·2
Range ..	23·8	13·5	11·4	12·7	18·3	27·7	26·5	28·9	29·7	30·5	30·3	28·3

The total rainfall of the year was 38·5 inches of which 36·57 inches, i.e., 94·8% of the total rainfall, fell during the rainy season, and out of 43·4 rainy days 40 were in this season (Table II). This will show that most of the rain fell during these four months. It often fell in torrents with intervals of bright periods. Prevalent high temperature minimised to a great extent the beneficial effect of the rainfall upon the soil. An appreciable amount of the surface soil, where unprotected, was washed off to low-lying areas owing to torrential rain. In such areas the salts which the rain water had dissolved during its course accumulate. The water content of the surface soil after the first rainfall of the season was found to be much higher than at lower levels (Table III). This is explained by the fact that the water rapidly flowed off after a heavy fall of rain and there was not enough time allowed for the water to percolate to a lower substratum. Later on in the season the water reached lower levels with the consequent rise in the ground water level.

TABLE II

(From Meteorological Tables)

—	June 1931	July 1931	August 1931	September 1931	October 1931	November 1931	December 1931	January 1932	February 1932	March 1932	April 1932	May 1932
Actual Rainfall	1·29	10·71″	9·63″	12·5″	3·73″	0	0	0	0·26″	0·08″	0·06″	0·24″
Per cent Rainfall	3·3	27·8	25·0	32·4	9·6	0	0	0	0·67	0·20	0·15	0·52
Actual Rainy days ..	1·9	13·4	12·9	10·1	3·6	0	0	0	0·6	0·2	0·2	0·5
Per cent Rainy days ..	4·3	30·8	29·7	23·2	8·2	0	0	0	1·3	0·46	0·46	1·1

The 1st week of June was the height of summer, while the 4th week of June marked the beginning of the rainy season.

TABLE III

Water content of the soil

	Quadrat I			Quadrat II			Quadrat IV		Quadrat VI			Quadrat VII		Quadrat X		
	0″	6″	12″	0″	6″	12″	0″	6″	0″	6″	12″	0″	6″	0″	6″	12″
1932																
1st week .. June	0·30	0·38	0·64	1·5	1·3	1·9	0·08	0·1	0·3	0·38	0·36	0·1	0·22	0·06	0·36	0·14
4th week .. June	6·5	1·9	1·5	5·8	2·5	1·9	15·9	2·04	8·5	6·1	2·2	17·09	5·4	7·7	6·8	0·96
2nd week .. July	0·67	3·08	2·6	0·59	2·7	5·2	0·85	0·48	0·79	2·9	3·6	1·6	1·2	0·81	6·01	6·4
4th week .. July	5·5	7·9	7·8	5·1	9·7	11·0	19·8	10·7	4·4	6·6	6·8	18·0	8·0	4·4	5·1	6·8
2nd week .. August	17·1	12·5	12·1	18·3	19·2	21·5	18·1	9·6	15·3	15·3	14·9	22·3	11·5	12·9	12·3	11·9
4th week .. August	13·1	12·7	7·1	11·03	16·0	13·5	7·4	7·7	6·6	8·2	8·4	7·1	8·4	4·7	8·2	9·3

Owing to hot sun and intense evaporation a severe drought was produced during the intervals of bright periods that occurred between the rainy days. These bright periods were sometimes sufficiently prolonged as in the June and July of 1932. First rain fell on the 21st June 1932 and after a couple of inches fall the rain stopped for over three weeks before the second rain fell on 20th July 1932. Large numbers of seedlings were killed as a result of the drought.

From Table IV it will be seen that between the first and second rain there was an interval of about three weeks and the number of seedlings that germinated after the first rainfall gradually dwindled down to a small figure before the second rain started. Table IV also shows that out of 247 seedlings in Quadrat number 1, that germinated after the first rain, only 10 could survive; but in the case of Quadrat 6 out of 588 seedlings 70 were able to withstand the adverse conditions. The death of a certain percentage of these seedlings may reasonably be ascribed to other factors than drought, but on the whole it seems that the majority of the seedlings were killed through adverse physical factors brought about by the absence of rain.

It may, however, be emphasized that the seedlings of different plants differed in their capacity to withstand adverse conditions. Thus, out of 203 seedlings of *Rungia parviflora* var. *pectinata* that germinated after the first rain only 4 were able to survive the drought, while in the case of the seedlings of *Commelina benghalensis* out of 14 seedlings that germinated four were able to survive. Again in Quadrat 6, 440 seedlings of *Vandellia crustacea* germinated but none could survive, while out of 67 seedlings of *Euphorbia hirta* 45 were able to withstand the adverse conditions in the same quadrat. The differing capacities of the seedlings of different plants to withstand adverse conditions will determine to a great extent the nature of the resulting plant community.

It will again be noticed from Table IV that just after the second rainfall (22-7-32) a new group of seeds that lay dormant during the period of drought germinated. The Table shows that just after the second rainfall the number of seedlings in Quadrat 1 increased from 10 to 177, in Quadrat 6 the number of seedlings increased from 70 to 232. The intermittent germination of seeds under such weather provided the plants with a new lease of life and enhanced their chances of survival. Salisbury (7) has also drawn attention to the importance of intermittent germination in the survival of certain plants. At the incidence of severe frost he has noticed that species with discontinuous germination survived while those with simultaneous germination were eliminated.

The total nitrate content of the surface soil was higher at the beginning of June when summer was at its height than in any other season. From Table V will be seen that the diphenylamine test

TABLE IV

Date.	Rainfall in Inches. (From Meteorological Tables)	Per cent Humidity (From Meteorological Tables)	Number of Seedlings in Quadrat I.	Number of Seedlings in Quadrat VI.	Number of Seedlings in Quadrat II.
20th June 1932 ..	0	21	..	..	..
21st ,, ,, ..	0·5	57	First	day of	rain
22nd ,, ,, ..	1·15	88	0	0	0
23rd ,, ,, ..	0·15	80	0	98	27
24th ,, ,, ..	0·20	87	0	143	45
25th ,, ,, ..	..	..	247	582	49
26th ,, ,, ..	..	..	249	588	49
27th ,, ,, ..	0	47	..	..	..
28th ,, ,, ..	0	33	244	575	48
29th ,, ,, ..	Showers	29	240	573	47
30th ,, ,, ..	Showers	76	214	472	44
1st July 1932 ..	Showers	44	203	441	46
2nd ,, ,, ..	0	58	200	429	45
3rd ,, ,, ..	0·25	..	..	..	..
4th ,, ,, ..	0	77	183	416	44
5th ,, ,, ..	0·15	57	161	398	44
6th ,, ,, ..	0	60	148	390	40
7th ,, ,, ..	0	65	143	363	36
8th ,, ,, ..	0·3	84	125	340	30
9th ,, ,, ..	Showers	48	128	322	26
10th ,, ,, ..	..	..	..	..	..
11th ,, ,, ..	0	52	..	..	..
12th ,, ,, ..	0	45	83	121	17
13th ,, ,, ..	Showers	54	28	101	19
14th ,, ,, ..	Showers	49	28	90	17

TABLE IV—(*continued*).

Date.	Rainfall in Inches. (From Meteorological Tables).	Per cent Humidity. (From Meteorological Tables).	Number of Seedlings in Quadrat I.	Number of Seedlings in Quadrat VI.	Number of Seedlings in Quadrat II.
15th July 1932 ..	..	37	23	80	18
16th „ „ ..	..	..	17	78	18
17th „ „ ..	Showers	..	..	..	..
18th „ „ ..	0	46	12	73	18
19th „ „ ..	0	38	11	70	18
20th „ „ ..	1·43	55	10	70	18
21st „ „ ..	1·60	71	10	73	18
22nd „ „ ..	0·80	53	42	77	18
23rd „ „ ..	0·12	59	177	232	18
24th „ „ ..	..	..	..	..	..
25th „ „ ..	0	45	168	252	22
26th „ „ ..	Showers	54	141	248	22
27th „ „ ..	Showers	59	121	246	22
28th „ „ ..	0·83	59	..	..	..
29th „ „ ..	0·65	78	131	248	25
30th „ „ ..	0·90	74	132	253	25
31st „ „ ..	..	..	..	..	..
1st August 1932 ..	0·72	64	142	296	25
2nd „ „ ..	0·30	82	144	278	28
3rd „ „ ..	0·12	87	..	..	..
4th „ „ ..	0·30	87	189	321	39
5th „ „ ..	Showers	82	189	323	42
6th „ „ ..	1·10	91	..	..	..
7th „ „ ..	..	..	..	..	..
8th „ „ ..	0·29	70	..	..	..

TABLE IV—*(continued)*.

Date.	Rainfall in Inches. (From Meteorological Tables.)	Per cent Humidity (From Meteorological Tables.)	Number of Seedlings in Quadrat I.	Number of Seedlings in Quadrat VI.	Number of Seedlings in Quadrat II.
9th August 1932 ..	0·24	69	..	..	..
10th " " ..	0·12	67	..	..	..
11th " " ..	0·50	76	..	..	..
12th " " ..	0·30	87	..	..	..
13th " " ..	Showers	72	..	..	..
14th " " ..	..	..	177	508	37
15th " " ..	0·12	79	..	..	..
16th " " ..	..	..	..	..	..
17th " " ..	1·14	78	..	..	..
18th " " ..	0	58	180	585	35
19th " " ..	0	58	..	..	..
20th " " ..	0	63	..	..	..
21st " " ..	..	..	..	..	..
22nd " " ..	2·3	60	..	..	..
23rd " " ..	Showers	54	..	..	..
24th " " ..	0	54	..	..	..
25th " " ..	..	..	..	..	..
26th " " ..	0	46	183	551	35
27th " " ..	0	39	..	..	..
28th " " ..	..	..	..	..	..
29th " " ..	0	42	..	..	..
30th " " ..	0	40	..	..	..
31st " " ..	0	34	171	347	52

showed a normally high quantity of nitrates in the surface soil. The amount of nitrates, however, suddenly fell with the depth. After

rainfall the nitrates were washed down to the lower layers of the soil (Table V). This amount of the nitrates was presumably lost in the deeper layers of the soil where it was available only to the deep-rooted plants.

The carbonate content of the soil in the plots studied (Table VI) did not show any appreciable variation from season to season, but, as pointed out before, large quantities of calcium carbonate are found deposited in old alluvium as irregular nodules. Where these nodules occur the cultivation becomes uneconomical and it is sooner or later given up. These nodules make good road surfaces for which purpose these are constantly removed.

If higher values of hydrogen-ion-concentration (pH) give any clue as to the high content of salts, then it will be evident from Table VII that there was higher concentration of salts on the surface soil during the hot season than in the rainy season. After rainfall the pH value fell immediately bringing the soil reaction more or less to neutral point.

The amount of humus as judged by the loss on ignition (Table VIII) was low. This low value is probably due to its rapid decomposition during hot weather, as is borne out by the fact that the total humus content of the soil was lower in the summer season than in the winter or rainy seasons.

In summing up the several factors it will be found that during the rainy season with the advent of monsoons, the water content of the soil increased, the temperature of the air as well as of the soil decreased considerably as compared with what it was during the summer. The nitrates and other salts were washed to lower substrata. There was a tendency towards the decrease of the total carbonates in the soil, and increase of organic matter on the surface of the soil. The reaction of the soil was less alkaline and on the whole the climatic and edaphic factors were very suitable for plant life.

The trees and shrubs, phanerophytes in Raunkiaer's terms, were either confined to waste lands, or to the edges of cultivated fields, road sides and gardens. The ground was covered with herbaceous plants at this time of the year. Different species were dominant at different places and in the quadrats studied it was found that in Quadrat 1 *Rungia parviflora* var. *pectinata* was dominant, grasses (*Andropogon* sp. and *Cynodon* sp.) were occupying a subordinate position. In Quadrat 2 grasses were dominant and yet in another quadrat *Sida veronicaefolia* was dominant. Grasses on the whole formed the characteristic feature of the physiognomy. It will be seen from Table IX that in the rainy season, owing to favourable conditions for plant growth, the largest number of plants were recorded per metre square area. The grasses were not included in the counts, with their inclusion the total number of plants per metre square area would have been more than twice as many.

TABLE V

Nitrate Content of the soil (Diphenylamine test.)

—	Quadrat I			Quadrat II			Quadrat IV		Quadrat VI			Quadrat VII		Quadrat X		
	0″	6″	12″	0″	6″	12″	0″	6″	0″	6″	12″	0″	6″	0″	6″	12″
1932																
1st Week June ..	+++	++	+	++++	+++	++	++	++	+++ +++	+++	++	+++ +++	++	+++ +++	++	+
4th Week June ..	++	++	+	+++	++	+	++	+	±	++	+	++++	+++	+	++++	+
2nd Week July ..	++	++	+++	+++	++	++	++	+	++	±	+	+	+	++	++	++++
4th Week July ..	++++	+	+	+++	+	+	+	+	+	±	±	+	+	++++	+	+++
2nd Week August ..	++	+	++	+	±	+	±	±	±	±	++	±	+	±	+	+
4th Week August ..	++	+	++	++	+	+	+	+	+	+	+	±	+	+	+	+

TABLE VI

Total Carbonates

—	Quadrat I			Quadrat II			Quadrat IV		Quadrat VI			Quadrat VII		Quadrat X		
	0″	6″	12″	0″	6″	12″	0″	6″	0″	6″	12″	0″	6″	0″	6″	12″
1932																
1st Week June	1·1	1·5	1·09	3·57	5·4	4·3	0	0	0·12	0·12	0·08	0·21	0·12	0·21	0·12	0·54
4th Week June	1·4	1·9	1·9	4·09	5·4	6·13	0	0	0·36	0·4	0	0·45	0	0·36	0·36	0·81
2nd Week July	1·3	2·0	0·9	3·2	4·5	4·3	0	0	0·204	0·16	0	0·2	0	0·4	0·57	3·2
4th Week July	1·6	1·7	1·8	4·3	4·5	4·6	0	0	0·38	0·22	0	0·22	0	0·36	0·28	0·13
2nd Week August	1·21	1·38	0·69	4·2	5·3	6·5	0	0	0	0	0·09	0·28	0·04	0·2	0·2	0·24
4th Week August	1·38	1·6	0·7	2·2	5·1	4·3	0	0	0.08	0	0·06	0·36	0 04	0·28	0·4	0·28
Average	1·3	1·7	1·2	3·6	5·0	5·0	0	0	0·19	0·15	0·08	0·28	0·03	0·2	0·32	0·86

TABLE VII

Hydrogen-ion-Concentration (pH) of the soil

—	Quadrat I.			Quadrat II.			Quadrat IV.		Quadrat VI.			Quadrat VII.		Quadrat X.		
	0″	6″	12″	0″	6″	12″	0″	6″	0″	6″	12″	0″	6″	0″	6″	12″
1932																
1st Week June	7·3	7·6	7·3	7·4	7·4	7·6	7·1	7·0	7·1	7·2	7·3	7·1	7·1	7·3	7·3	7·3
4th Week June	7·0	7·2	7·2	7·2	7·3	7·4	7·1	6·7	6·8	7·2	7·1	6·8	6·6	7·1	7·2	7.2
2nd Week July	7·0	7·3	7·2	7·2	7·2	7·2	6·9	6·4	7·0	7·2	7·0	7·0	6·6	7·2	7·2	7·2
4th Week July	7·0	7·2	7·0	7·2	7·1	7·3	6·5	6·6	7·0	7·0	6·8	6·8	6·8	7·2	7·1	7·2
2nd Week August	7·2	7·2	7·2	7·5	7·4	6·9	6·9	7·0	7·1	7·0	7·1	7·2	7·0	7·1	7·2	7·2
4th Week August	6·9	7·2	7·2	7·3	7·4	7·2	7·2	6·9	7·0	7·1	7·1	7·4	7·2	7·2	7·2	7·2
Average	7·0	7·3	7·2	7·3	7·3	7·2	6·9	6·7	7·0	7·1	7·0	7·0	7·0	7·2	7·2	7·2

TABLE VIII

Loss on ignition of the soil

—	Quadrat I.			Quadrat II.			Quadrat IV.		Quadrat VI.			Quadrat VII.		Quadrat X.		
	0″	6″	12″	0″	6″	12″	0″	6″	0″	6″	12″	0″	6″	0″	6″	12″
1932																
1st Week June	4·3	3·4	2·7	5·7	5·4	4·4	5·08	2·8	2·7	3·3	1·8	5·6	1·4	2·8	1·08	2·6
4th Week June	5·5	3·4	3·1	4·4	4·2	5·5	7·01	1·9	3·4	2·9	2·5	5·5	2·05	2·5	2·8	2·3
2nd Week July	5·6	4·04	2·6	4·8	4·6	5·2	3·3	2·3	3·06	·95	2·4	6·04	2·1	3·6	3·3	3·6
4th Week July	6·4	3·5	3·59	4·7	4·0	2·6	4·51	2·17	3·06	3·7	3·3	5·5	·68	2·4	2·2	1·4
2nd Week August	4·0	2·6	2·9	5·3	4·1	1·7	4·05	1·6	2·9	2·1	3·4	6·4	3·3	2·4	2·7	1·21
4th Week August	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Average	5·1	3·4	2·9	5·0	4·4	3·9	4·8	2·1	3·0	2·6	2·7	5·8	2·3	2·7	2·4	2·2

Most of the herbaceous plants were therophytes, *i.e.*, they passed the unfavourable period in the seed stage. In certain cases the life cycle was completed very quickly, and specimens of *Bonnaya bracheata* and *Vandellia crustacea* were found to bear flowers, while the cotyledons were still green. It was very difficult to say in such cases the age up to which the seedling stage persisted. The hot dry season was tided over by these plants in the seed stage and just after the first rains, when the conditions for germination became favourable, the first to appear were grasses. The germination of other seeds was delayed by a day, but there was prolific outgrowth of seelings and the whole ground was overcrowded with herbaceous plants within a few days after the first rain. It has been pointed out previously that during this time when rain stopped for a few days the surface soil became dry, causing the death of many of the seedlings. If the seeds of such plants germinated intermittently their chances of survival were enhanced in these sudden changes of climate.

The first appearance even of grasses, which are otherwise known to spread vegetatively during the growing period, was through the germination of seeds. Other plants also while they tided over the summer conditions in the seed stage spread vegetatively during the growing season. Such a case was found with *Rungia parviflora* var. *pectinata* and it was true of a number of other plants as well.

During the rainy season water accumulates in depressions and a few hydrophytes make their appearance, but these investigations were confined only to the land plants.

The characteristic vegetation during this season was hygrophilous on the whole and it was in the rainy season that the tropical aspect of the flora as well as its composition appeared more clearly.

2. *The Winter Season*:—The winter season extended, as it does, from October to the end of February. It was followed by a short-lived spring. During this season the temperature was lower than in the rainy season. The mean maximum temperature was 88°F. in October, 77°F. in December and 80°F. in February. The range between maximum and minimum temperature was greatest during this season, *i.e.*, 30°F. in February. The lowest temperature recorded was 49°F. but in some abnormal years it may fall as low as the freezing point. The humidity of the air was high and owing to great range between maximum and minimum temperatures there was copious fall of dew. This, to some extent, compensated for the paucity of rainfall during the winter season. The days were usually sunny although in normal years there is some rainfall during December and January. In Quadrat 1 investigations on the soil were carried out at seven spots (Table X) within a metre square area at surface, 6 inches and 12 inches depth. Table X shows that within this small area, some variation was found in

TABLE IX

Total Number of Plants in each Quadrat

Quadrat Number.	Sept. 1931.	Nov. 1931.	Dec. 1931.	1st week Jan. 1932.	4th week Jan. 1932.	2nd week Feb. 1932.	4th week Feb. 1932.	2nd week March 1932.	2nd week April 1932.	1st week May 1932.	1st week June 1932.	4th week June 1932.	2nd week July 1932	4th week July 1932.	2nd week Aug. 1932.	Last week Aug. 1932.
I ..	509	436	356	325	314	118	82	36	18	7	5	5	41	126	184	160
II ..	462	..	41	41	38	35	35	32	31	22	9	3	20	24	37	34
IV ..	..	123	123	108	55	40	21	19	15	7	2	2	26	29	236	532
VI ..	..	..	161	126	100	70	63	45	29	10	6	4	96	246	585	347
VII ..	..	..	205	164	122	102	96	63	45	37	30	25	128	259	337	302
VIII ..	..	..	..	87	122	119	81	74	55	40	12	0	0	127	118	93

nitrates, carbonates and water content of the soil. It may, however, be pointed out that there was no observable difference between the plants growing in this area.

The number of plants per square metre area decreased considerably during the winter season in comparison with the number in the rainy season. Ephemeral plants of the rainy season withered away, after shedding their seeds, by the end of October; others flowered and fruited during this season. The hygrophilous annuals were replaced by mesophytic annuals of temperate connections. The plants of the family compositae were dominant. Perennials lost their tropcial luxuriance. In Quadrat 1 there were (exclusive of grasses) 509 plants of 13 different species in September but in December there were only 356 plants of 8 different species.

3. *The Summer Season*:—The summer season extended from early in March till the middle of June. The first few weeks may be considered as spring. The temperature during these months gradually rose and went up as high as 120°F. The mean maximum temperature, however, was 92·7°F. in March which gradually increased to 107°F. in June. The range between Maximum and Minimum temperature decreased. The nights were only slightly cooler than the days. The dry hot winds blew fiercely throughout these months and everything seemed parched. Humidity was very low and there was no rain during this season.

The water content of the surface soil was very low, but some water was present at lower depths. There was accumulation of salts on the surface of the soil, due to the action of ground water which rose by capillarity owing to excessive evaporation on the surface. The reaction of the soil was alkaline and there was increase in the nitrate content. The main constituents of this white alkali were chlorides and sulphates of sodium.

Due to the extremes of temperature and drought all the herbaceous plants died down except in protected places where perennials were left behind. Apart from trees and shrubs the ground was bare of plants.

The month of March was characterised by dry strong winds which brought about the leaf fall of the deciduous trees. The new leaves on these trees and shrubs appeared by the end of April. It has been erroneously stated that these trees shed their leaves in order to tide over the hot weather. It is found on the other hand that these trees sprout forth and bear a new cover of leaves in the height of summer.

A. Howard (6) in his paper "On the effect of grass on trees" drew attention to this feature. The data collected by him shows that the root system of these trees is of two types, the first one

TABLE X

Investigations on the soil from seven spots in Quadrat I (17th February 1932)

Spot No.	Water Content of soil.			Hydrogen-ion Concentration (pH) of Soil.			Nitrates present in soil (Diphenylamine test.)			Total Carbonate gm. per 100 gm. of Soil.			Loss on ignition gm. per 100 gm. of Soil.		
	0″	6″	12″	0″	6″	12″	0″	6″	12″	0″	6″	12″	0″	6″	12″
1	0·80	1·93	1·31	7·0	7·1	7·0	±	±	±	1·36	1·88	0·26	4·22	3·59	2·43
2	0·12	1·78	2·75	6·9	7·1	7·1	±	++ ++	±	1·16	2·77	0·61	4·31	3·9	2·61
3	0·40	1·46	1·87	7·1	7·1	6·9	±	±	±	1·22	1·50	0·48	4·64	3·92	2·72
4	0·84	1·25	1·41	7·0	7·1	7·1	±	±	±	1·3	1·54	0·46	4·10	3 54	2·35
5	0·50	1·01	1·66	6·9	7·0	6·6	±	±	±	1·28	1·30	0·26	4·28	3·78	2·20
6	1·15	1·91	4·14	7·1	7·2	7·1	±	±	±	1·05	1·88	1·48	4·67	3·67	3·35
7	0·54	1·29	1·95	7·0	7·2	7·1	±	±	±	0·96	1·00	0·70	4·82	3·1	3·52
Average.	0·62	1·51	2·15	7·0	7·1	6·9	..	..	..	1·19	1·69	0·60	4·43	3·64	2·75

being superficial which is active during the rainy season and the second one deep seated which functions in the dry season. These trees because of their deep seated root system can draw upon the ground water during the dry season and do not suffer for the want of water. There is scanty nitrogen at the ground water level and consequently the foliage formed during this season is paler compared with those formed during the rainy season. The superficial root-system is active during the rainy season but with the increase of the dryness the activity of the root shifts downwards till in summer it reaches its lowest depth. Thus in *Mangifera indica* the active root-system in October was not found to extend beyond 3 feet 6 inches and in January not below 7 feet 6 inches and in the month of March extended to 15 feet 6 inches. The region of activity shifts downwards with the fall in ground water level. In the rainy season, however, with the rise in ground water level the root activity becomes more and more superficial. The foliage attains the deep green colour showing that nitrates are absorbed from levels nearer the surface.

Conclusions

It will be noticed from the foregoing description that the climatic factors, *e.g.*, rainfall, temperature, etc., are mainly responsible, directly, or indirectly by effecting changes in soil conditions, for bringing about seasonal changes in vegetation. The soil factors, in the quadrats studied, remained relatively constant. Within the course of a year a seasonal change of flora from tropical to temperate and to desert conditions takes place; the vegetation therefore consists of a mixed population of plants. The seasonal variation of the climatic factors is so great that a species can, only with difficulty, remain dominant throughout the year; thus restricting the number of indigenous species. According to Hooker (5), the number of indigenous species in the region (Gangetic Plain) is small, possibly amounting to 1,500 under 112 orders of which the following ten are dominant:—

1. Gramineae.
2. Leguminosae.
3. Cyperaceae.
4. Compositae.
5. Scrophulariaceae
6. Malvaceae.
7. Acanthaceae.
8. Euphorbiaceae.
9. Convolvulaceae.
10. Labiatae.

Seven of these are cosmopolitan, while Malvaceae and Convolvulaceae are temperate and Acanthaceae tropical. Of the 28 different species

met with in the quadrats studied 16 were tropical and 12 were temperate.

The classification of such a plant community presents a certain amount of difficulty, but they are conveniently grouped into Synusia. A synusium according to Gam's is an aggregation of plants which belong to the same life form and make similar demands upon a similar habitat. Saxton (8) though not adhering strictly to this definition made an attempt to classify the plants of the locality he studied into 8 synusia. A synusium in such a case will form the fundamental unit of vegetation and an association will consist of a group of synusia just as a formation consists of a group of associations.

This area is thickly populated and man exerts considerable influence upon the character of the vegetation. According to Dudgeon (3) the present vegetation is in the dry meadow stage and would develop into a deciduous monsoon forest if left undisturbed by man. It is, however, very difficult to predict without further investigation the nature of forest which would develop after the removal of man's influence. Prof. Dudgeon may perhaps be right. There is very intimate connection between the activities of man and the character of the surrounding vegetation. Man utilises the vegetable products for the necessaries of his own life and those of his domesticated animals; therefore he is responsible for interference and some destruction of the vegetation. The demand by man upon the vegetation increases with the growth of population and the vegetation in course of time attains equilibrium. From the earliest record of the vegetation of this region by Thomas Anderson (1) it appears that the vegetation of to-day is not much different from that of a century ago. The vegetation is arrested, most probably deflected, from attaining the climatic climax. It appears to be a pro-climax; the chief determining factor being man.

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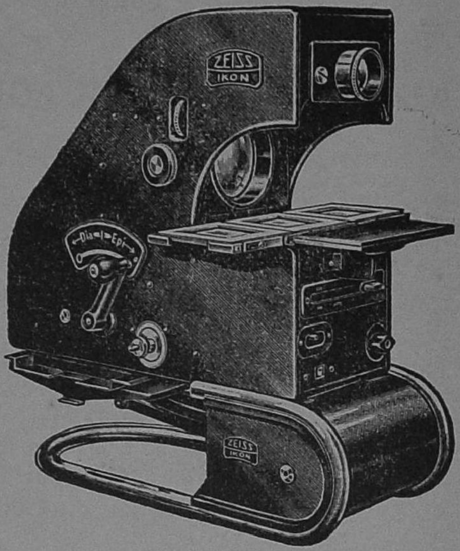

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